



TFW 1632

PTO/SB/21 (09-04)

Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMITTAL FORM (to be used for all correspondence after initial filing)	Application Number	10/500,521	
	Filing Date	February 18, 2005	
	First Named Inventor	Gideon Schreiber	
	Art Unit	1632	
	Examiner Name	Sajjadi, Fereydoun Ghotb	
Total Number of Pages in This Submission	40	Attorney Docket Number	05558.0018.PCUS00

ENCLOSURES (Check all that apply)		
<input type="checkbox"/> Fee Transmittal Form <input type="checkbox"/> Fee Attached <input type="checkbox"/> Amendment/Reply <input type="checkbox"/> After Final <input type="checkbox"/> Affidavits/declaration(s) <input type="checkbox"/> Extension of Time Request <input type="checkbox"/> Express Abandonment Request <input type="checkbox"/> Information Disclosure Statement <input type="checkbox"/> Certified Copy of Priority Document(s) <input type="checkbox"/> Response to Missing Parts/ Incomplete Application <input type="checkbox"/> Response to Missing Parts under 37 CFR 1.52 or 1.53	<input type="checkbox"/> Drawing(s) <input type="checkbox"/> Licensing-related Papers <input type="checkbox"/> Petition <input type="checkbox"/> Petition to Convert to a Provisional Application <input type="checkbox"/> Power of Attorney, Revocation Change of Correspondence Address <input type="checkbox"/> Terminal Disclaimer <input type="checkbox"/> Request for Refund <input type="checkbox"/> CD, Number of CD(s) <input type="checkbox"/> Landscape Table on CD	<input type="checkbox"/> After Allowance Communication to TC <input type="checkbox"/> Appeal Communication to Board of Appeals and Interferences <input type="checkbox"/> Appeal Communication to TC (Appeal Notice, Brief, Reply Brief) <input type="checkbox"/> Proprietary Information <input type="checkbox"/> Status Letter <input checked="" type="checkbox"/> Other Enclosure(s) (please identify below): Certified copy of priority document, Israel International Application No. PCT/IL02/01059, and return-receipt postcard.
Remarks		

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT			
Firm Name	Howrey LLP		
Signature			
Printed name	David W. Clough, Ph.D.		
Date	April 7, 2006	Reg. No.	36,107

CERTIFICATE OF TRANSMISSION/MAILING			
I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below.			
Signature			
Typed or printed name	David W. Clough, Ph.D.	Date	April 7, 2006

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.



PATENT

Attorney Docket No. 05558.0018.PCUS00

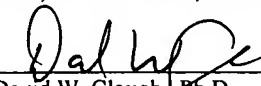
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Gideon Schreiber
App. No.: 10/500,521
Conf. No.: 7709
Filing Date: February 18, 2005
Title: IFNAR2 MUTANTS, THEIR PRODUCT
AND USE
Art Unit: 1633
Examiner: Sajjadi, Fereydoun Ghotb

CERTIFICATE OF MAILING

I hereby certify that this paper is being deposited with the United States Postal Service as first class mail in an envelope addressed to:
Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, on this date:

04/07/06
Date


David W. Clough, Ph.D.
Registration No. 36,107

SUBMISSION OF CERTIFIED COPY OF PRIORITY DOCUMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:


Applicant hereby submits a certified copy of the priority document, Israel International Patent Application PCT/IL02/01059, filed December 31, 2002 in connection with the above-referenced patent application.

Respectfully submitted,

HOWREY LLP

Dated: April 7, 2006

By:


David W. Clough, Ph.D.
Registration No.: 36,107
Customer No.: 22930

HOWREY LLP
321 N. Clark Street, Suite 3400
Chicago, IL 60661
(312) 595-1239 (main)
(312) 595-1408 (direct)
(312) 595-2250 (fax)



BEST AVAILABLE COPY

CERTIFIED COPY OF
PRIORITY DOCUMENT

מדינת ישראל
STATE OF ISRAEL

Ministry of Justice
Patent Office

משרד המשפטים
לשכת הפטנטים

to certify that annexed
is a true copy of the
as originally
with the patent
of which
are specified on the
the annex.

זאת לתעודה כי רצופים בזה
העתקים נכונים של המסמכים
שהופקדו לכתחילה עם
הבקשה לפטנט לפי הפרטים
הרשומים בעמוד הראשון של
הנספח.

This 18-12-2003 היום

רשם הפטנטים

Commissioner of Patents

ד"ר מאיר כהנא
רשם הפטנטים
משרד המשפטים

נתאשר
Certified

לשימוש הלשכה
For Office Use

מספר : 147414 Number
תאריך : 31-12-2001 Date הוקדם/נדחה Ante/Post-dated

בקשה לפטנט
Application for Patent

אני, (שם, המבקש, מענו ולגבי גוף מאוגד - מקום התאגדותו)
I (Name and address of applicant, and in case of body corporate - place of incorporation)

SCHREIBER GIDEON: ממציא
Yeda Research and Development Co. Ltd
An Israeli Company
At Weizmann Institute of Science
P.O.Box 95
Rehovot 76100, Israel.

ידע חברה למחקר ולפיתוח בע"מ
חברה ישראלית
ליד מכון ויצמן למדע
ת.ד. 95
רחובות 76100

Owner, by virtue of : Assignment

בעל אמצאה מכח
of העברה

an invention the title of which is
(Hebrew)

ששמה הוא מוטנטים של IFNAR2 הכנתם והשימוש בהם
(בעברית)

IFNAR2 MUTANTS, THEIR PRODUCTION AND USE

(English)

(באנגלית)

hereby apply for a patent to be granted to me in respect thereof.

מבקש בזאת כי יינתן עליה פטנט

• בקשת חלוקה - Application of Division		• בקשת פטנט מוסף - Application for Patent Addition		דרישת דין קדימה Priority Claim	
מבקשת פטנט from Application No. Dated	מס' מיום	• לבקשה/לפטנט to Patent/Appl. No. Dated	מס' מיום	מספר/סימן Number/Mark	תאריך Date
מדינת האגוד Convention Country					
• ייפוי כוח: כללי/ מיוחד - רצוף בזה/ עוד יוגש P.O.A.: general/ individual - attached/to be filed later הוגש בעניין filed in case					
המען למסירת מסמכים בישראל: Address for Service in Israel הנרי עינב - עורך פטנטים. אינטר-לאב בע"מ קרית ויצמן נס ציונה 76100					

For the Applicant: Signature of Applicant הנרי עינב-עורך פטנטים Henry Einav - Patent Attorney
--

היום 31 בחודש דצמבר שנת 2001
This 31 of the year December of 2001

לשימוש הלשכה
For Office Use

527

טופס זה, כשהוא מוטבע בחותם לשכת הפטנטים ומושלם במספר ובתאריך ההגשה, הינו אישור להגשת הבקשה שפרטיה רשומים לעיל.
This form, impressed with the Seal of the Patent Office and indicating the number and date of filling, certifies the filing of the application the particulars of which are set out above.

Delete whatever is inapplicable

• מחק את המיותר

IFNAR2 MUTANTS,
THEIR PRODUCTION AND USE

מוטנטים של IFNAR2 , הכנתם והשימוש בהם

FIELD OF THE INVENTION

The present invention relates to a mutant of the beta chain of the type I IFN receptor (IFNAR2 mutant) with enhanced affinity to interferon-beta with respect to the wild type protein and to a complex, comprising the mutant IFNAR2 extracellular domain and IFN β for improving the stability, potency, and prolonging the pharmacokinetics *in vivo* of free IFN β .

BACKGROUND OF THE INVENTION

Interferons are classified either as the leukocyte and fibroblast derived Type I interferons, or as the mitogen induced or "immune" Type II interferons (Pestka et al, 1987). Through analysis of sequence identities and common biological activities, type I interferons include interferon alpha (IFN α), interferon beta (IFN β) and interferon omega (IFN ω), while type II interferon includes interferon gamma (IFN γ).

The IFN α , IFN β and IFN ω genes are clustered on the short arm 25 of chromosome 9 (Lengyl, 1982). There are at least 25 non-allelic IFN α genes, 6 non-allelic IFN ω genes and a single IFN β gene. All are believed to have evolved from a single common ancestral gene. Within species, IFN α genes share at least 80% sequence identity with each other. The IFN β gene shares approximately 50% sequence identity with IFN α ; and the IFN ω gene shares 70% homology with IFN α (Weissman et al, 1986; Dron et al, 1992). IFN α has a molecular weight range of 17-23 kDa (165-166 amino acids), IFN β , about 23 kDa (166 amino acids) and IFN ω , about 24 kDa (172 amino acids).

Type I interferons are pleiotropic cytokines having activity such as host defense against viral and parasitic infections, anti-cancer properties and as immune modulators (Baron et al, 1994; Baron et al, 1991). Type I interferon physiological responses include anti-proliferative activity on normal and transformed cells, stimulation of cytotoxic activity in lymphocytes, natural killer cells and phagocytic cells, modulation of cellular differentiation, stimulation of expression of class I MHC antigens, inhibition of class II MHC, and modulation of a variety of cell surface receptors. Under normal physiological conditions, IFN α and IFN β (IFN α/β) are secreted constitutively by most human cells at low levels with expression being up-regulated by addition of a variety

of inducers, comprising infectious agents (viruses, bacteria, mycoplasma and protozoa), dsRNA, and cytokines (M-CSF, IL-1 α , IL-2, TNF α). The actions of Type I interferon *in vivo* can be monitored using the surrogate markers, neopterin, 2', 5' oligoadenylate synthetase, and β 2 microglobulin (Alam et al, 1997; Fierlbeck et al, 1996; Salmon et al, 1996).

Type I interferons (IFN $\alpha/\beta/\omega$) act through a cell surface receptor complex to induce specific biologic effects, such as anti-viral, anti-tumor, and immune modulators. The type I IFN receptor (IFNAR) is a hetero- multimeric receptor complex composed of at least two different polypeptide chains (Colamonici et al, 1992; Colamonici et al, 1993; Platanias et al, 1993). The genes coding for these chains are found on chromosome 21, and their proteins are expressed on the surface of most cells (Tan et al, 1973). The receptor chains were originally designated alpha and beta and have been renamed IFNAR1 for the alpha subunit and IFNAR2 for the beta subunit. In most cells, IFNAR1 (alpha chain, Uze subunit) (Uze et al, 1990) has a molecular weight of 100-130 kDa, while IFNAR2 (beta chain, β_L , IFN α/β R) has a molecular weight of 100 kDa. In certain cell types (monocytic cell lines and normal bone marrow cells) an alternate receptor complex has been identified, where the IFNAR2 subunit (β_S) is expressed as a truncated receptor with a molecular weight of 51 kDa. The IFNAR1 and IFNAR2 β_S and β_L subunits have been cloned (Novick et al, 1994; Domanski et al, 1995). The IFNAR2 β_S and β_L subunits have identical extracellular and transmembrane domains; however, in the cytoplasmic domain they only share identity in the first 15 amino acids. The IFNAR2 subunit alone is able to bind IFN α/β , while the IFNAR1 subunit is unable to bind IFN α/β . When the human IFNAR1 receptor subunit alone was transfected into murine L-929 fibroblasts, no human IFN α s except IFN α 8/IFN α B were able to bind to the cells (Uze et al, 1990). The human IFNAR2 subunit, transfected into L cells in the absence of the human IFNAR1 subunit, bind human IFN α , binding with a Kd of approximately 0.45 nM. When human IFNAR2 subunits were transfected in the presence of the human IFNAR1 subunit, high affinity binding could be shown with a Kd of 0.026-0.114 nM (Novick et al, 1994; Domanski et al, 1995). It is estimated that from 500- 20,000 high affinity and 2,000-100,000 low affinity IFN binding sites exist on most cells. Although the IFNAR1/2 complex (α/β_S or α/β_L) subunits bind IFN α with high affinity, only the α/β_L pair appears to be a functional signaling receptor.

Transfection of the IFNAR1 and the IFNAR2 β_L subunits into mouse L-929 cells, followed by incubation with IFN α 2, induces an anti-viral state, initiates intracellular protein phosphorylation, and causes the activation of intracellular kinases (Jak1 and Tyk2) and transcription factors (STAT 1, 2, and 3) (Novick et al, 1994; Domanski et al, 1995). In a corresponding experiment, transfection of the IFNAR2 β_S subunit was unable to initiate a similar response. Thus, the IFNAR2 β_L subunit is required for functional activity (anti-viral response) with maximal induction occurring in association with the IFNAR1 subunit.

In addition to membrane bound cell surface IFNAR forms, a soluble IFNAR has been identified in both human urine and serum (Novick et al, 1994; Novick et al, 1995; Novick et al, 1992; Lutfalla et al, 1995). The soluble IFNAR isolated from serum has an apparent molecular weight of 55 kDa on SDS- PAGE, while the soluble IFNAR from urine has an apparent molecular weight of 40-45 kDa (p40). Transcripts for the soluble p40 IFNAR2 are present at the mRNA level and encompass almost the entire extracellular domain of the IFNAR2 subunit with two additional amino acids at the carboxy terminal end. There are five potential glycosylation sites on the soluble IFNAR2 receptor. The soluble p40 IFNAR2 has been shown to bind IFN α 2 and IFN β and to inhibit *in vitro* the anti-viral activity of a mixture of IFN α species ("leukocyte IFN") and individual Type I IFNs (Novick et al, 1995). A recombinant IFNAR2 subunit Ig fusion protein was shown to inhibit the binding of a variety of Type I IFN species (IFN α A, IFN α B, IFN α D, IFN β , IFN α Con1 and IFN ω) to Daudi cells and α/β_S subunit double transfected COS cells.

Type I IFN signaling pathways have been identified (Platanias et al, 1996; Yan et al, 1996; Qureshi et al, 1996; Duncan et al, 1996; Sharf et al, 1995; Yang et al, 1996). Initial events leading to signaling are thought to occur by the binding of IFN $\alpha/\beta/\omega$ to the IFNAR2 subunit, followed by the IFNAR1 subunit associating to form an IFNAR1/2 complex (Platanias et al, 1994). The binding of IFN $\alpha/\beta/\omega$ to the IFNAR1/2 complex results in the activation of two Janus kinases (Jak1 and Tyk2), which are believed to phosphorylate specific tyrosines on the IFNAR1 and IFNAR2 subunits. Once these subunits are phosphorylated, STAT molecules (STAT 1, 2 and 3) are phosphorylated, which results in dimerization of STAT transcription complexes followed by nuclear localization of the transcription complex and the activation of specific IFN inducible genes.

A randomized, double-blinded, placebo-controlled, two-year multicenter study demonstrated that natural human fibroblast interferon (interferon beta) administered intrathecally (IT) is effective in reducing the exacerbations of exacerbating-relapsing multiple sclerosis (MS). The mean reduction in exacerbation rate of 34 patients with MS who received interferon beta administered IT was significantly greater during the study than that of 35 control patients who received placebo (Jacobs et al. 1987).

The pharmacokinetics and pharmacodynamics of Type I IFNs have been assessed in humans (Alan et al, 1997; Fierlbeck et al. 1996; Salmon et al. 1996). The clearance of IFN β is fairly rapid with the bioavailability of IFN β lower than expected for most cytokines. Although the pharmacodynamics of IFN β has been assessed in humans, no clear correlation has been established between the bioavailability of IFN β and clinical efficacy. In normal healthy human volunteers, administration of a single intravenous (iv) bolus dose (6 MIU) of recombinant CHO derived IFN β resulted in a rapid distribution phase of 5 minutes and a terminal half-life of about 5 hours (Alan et al, 1997). Following subcutaneous (sc) or intramuscular (im) administration of IFN β , serum levels are flat with only about 15% of the dose systemically available. The pharmacodynamics of IFN β following iv, im or sc administration (as measured by changes in 2'5'-oligoadenylate synthetase (2', 5'-AS) activity in PBMCs) were elevated within the first 24 hours and slowly decreased to baseline levels over the next 4 days. The magnitude and duration of the biologic effect was the same regardless of the route of administration.

A multiple dose pharmacodynamic study of IFN β has been conducted in human melanoma patients (Fierlbeck et al, 1996) with IFN β being administered by sc route, three times per week at 3 MIU/dose over a six-month period. The pharmacodynamic markers, 2', 5' -AS synthetase, β_2 - microglobulin, neopterin, and NK cell activation peaked by the second injection (day 4) and dropped off by 28 days, remaining only slightly elevated out to six months.

Purification and refolding of the extracellular part of human IFNAR2 (IFNAR2-EC) expressed in *Escherichia coli* and its characterization with respect to its interaction with interferon alpha2 (IFN α_2) has been reported (Piehler and Schreiber 199A). The 25 kDa. non-glycosylated IFNAR2-EC was shown to be a stable, fully active protein, which inhibits antiviral activity of IFN α_2 . The stoichiometry of binding IFN α_2 is 1:1,

as determined by gel filtration, chemical cross-linking and solid-phase detection. The affinity of this interaction was found to be about 3 nM (Piehler and Schreiber 2001). The rate of complex formation is relatively high compared to other cytokine-receptor interactions. The salt dependence of the association kinetics suggests a limited but significant contribution of electrostatic forces towards the rate of complex formation. The dissociation constant increases with decreasing pH according to the protonation of a base with a pKa of 6.7. The affinity of IFN β to IFNAR2 is about two-fold higher than that of IFN α 2 to IFNAR2 (Piehler and Schreiber 1999B).

Single mutations in the binding site of IFNAR2 allowed mapping of differences in binding of IF α 2 and IFN β (Piehler and Schreiber 1999B). For example, a mutation H78A was found to stabilize the complex with IFN β nearly by two fold, while destabilized the complex with IF α 2 more than two fold. A mutation N100A was found to hardly affect the rates for binding IF α 2, whereas it decreased the dissociation rate constant for IFN β by almost four folds.

EP1037658 discloses that the in vivo effect of Type I interferon (IFN) can be prolonged by administering the interferon in the form of a complex with an IFN binding chain of the human interferon alpha / beta receptor (IFNAR) i.e. IFNAR behaves as a carrier protein for IFN. Such a complex also improves the stability of the IFN and enhances the potency of the IFN. The complex may be a non-covalent complex or one in which the IFN and the IFNAR are bound by a covalent bond or a peptide. EP1037658 also discloses that storing IFN in the form of such a complex improves the storage life of the IFN and permits storage under milder conditions than would otherwise be possible.

There exists a need for an IFNAR2 with improved affinity towards IFN β , but not to IFN α 2, making IFNAR2 a better and specific carrier for IFN β .

SUMMARY OF THE INVENTION

The invention provides an IFNAR2 mutant mutated at amino acid residue histidine 78 and asparagine 100, an analogue, derivative or fragment thereof with increased affinity to IFN β than the wild type IFNAR2. The mutations are substitutions of amino acid, preferable conservative amino acids, more preferable alanine, aspartic acid and histidine. The IFNAR2 mutant has about 25, preferably 50 and more preferably 100-fold higher affinity than the wild type protein and an affinity of about 30 pM.

More particularly the invention provides an IFNAR2 fragment comprising the extracellular domain.

In another aspect the invention provides the use of an IFNAR2 mutant for the manufacture of a medicament for modulating the positive or negative effects of IFN, preferably IFN β , in vivo by improving or under certain conditions inhibiting the activity of IFN respectively.

The invention also provides a pharmaceutical composition comprising a therapeutically effective amount of an IFNAR2 mutant or its extracellular domain fragment, to be administrated alone or co-administrated with IFN, more preferably IFN β , separately or covalently bound. More specifically the invention provides pharmaceutical compositions for augmenting the anti-viral, anti-cancer and immune modulating properties of IFN, preferably IFN β for treatment of neurodegenerative diseases, more preferably multiple sclerosis (MS).

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 (left) depicts a simulation of the concentrations of bound and free IFN β using a constant concentration of IFN (50 pM) and increasing concentrations of with type IFNAR2 EC (left) and mutant IFNAR2 EC (right), with a K_d of 3 nM and 50 pM respectively, calculated in accordance with the law of mass action.

Figure 2 shows the amino acid sequence of the extracellular domain IFNAR2 protein (not including the leader sequence) and the modified amino acid residues (marked with an asterisk).

Figure 3 shows the binding of IFN β and IFN α 2 to the IFNAR2 EC H78A/N100A mutant. Association and disassociation of IFN β and IFN α 2 to the Wild type IFNAR2 EC (upper panel), to the IFNAR2 EC H78A/N100A mutant (middle panel) and the binding of the wild type and mutant IFNAR2 EC H78A/N100A mutant to IFN β (Lower panel) was measured using reflectometric interference spectroscopy (RiFS), with IFNAR2 immobilized to the surface (described in Piehler and Schreiber 2001). Y-axis = signal (nanometer) and the X-axis = time (seconds).

Figure 4 shows occlusion of IFN β by IFNAR2 wild type and mutants. A constant amount of IFN β (10 pM) was mixed with different concentrations of IFNAR2 (R2) wild type and mutants (single mutants R2N100A and R2H78A, double mutants R2 H78A/N100A, R2 H78A/N100H and R2 H78A/N100D), and the residual antiviral activity at equilibrium was determined in WISH cells. In the upper box, a plot of the antiviral activity of IFN β as a function of its concentration in the absence of IFNAR2 is shown (Y-axis = survival index). This plot is used as a standard to determine how much of the IFN β is free (active) in the anti-viral assay.

DETAILED DESCRIPTION OF THE INVENTION

The invention relates to an IFNAR2 mutated twice at amino acid residues H78 and N100 of the wild type IFNAR2 (Figure 2, SEQ ID N: 1) and biologically active analogs thereof with increased affinity to IFN β , but not to IFN α 2 (MIFNAR2). The invention relates also to the improved carrier activity of the extracellular domain of MIFNAR2 towards IFN β .

Figure 1 (left panel) depicts a simulation of the concentration of bound and free IFN β in the presence of different concentrations of IFNAR2 based on the law of mass action and on a K_d of 3nM (tested by reflectometric interference spectroscopy [RifS]). This simulation shows that in order to achieve 20 % of free IFN β (10 pM, which equals about 100 Units), and 80 % bound, a very high concentration of IFNAR2 protein such as 12.5 nM (which is equivalent to 300 μ g/Kg of non-glycosylated IFNAR2) is needed. This problem may be solved by administering a covalently bound complex as disclosed in WO9932141, in which the IFNAR2 EC domain is covalently linked to IFN β .

However, whenever the administration of non linked proteins is desired, using an IFNAR2 mutant with 50 fold and higher affinities to IFN β as a carrier (see simulation Figure 1, right panel), would be advantageous since with such a mutant theoretically only about 0.24 nM will be required to get 20 % IFN β free (which is equivalent to 6 μ g/Kg).

Thus, such a mutant of the IFNAR2 extracellular domain with increased affinity to IFN (MIFNAR2-EC) was generated. MIFNAR2-EC is modified in two amino acids, histidine at residue 78 and asparagine at residue 100 (Figure 2, SEQ ID NO:1). This mutant protein turned out to be a better carrier not only because its improved effectivity but also due to the fact that its affinity and consequently its effectivity was improved specifically towards IFN β , i.e. the affinity of the mutants to IFN β is about 26, 40 and above 50 fold higher than that of the wild type in contrast to its affinity towards IFN α 2 which remains unchanged (Table 1). Despite the increased affinity of this mutated soluble receptor (K_d of the H78A/N100A IFNAR2 mutant \sim 30pM versus K_d of WT protein = 3nM), enough IFN β remains unbound and therapeutically active, as evidenced by the anti-viral protective activity of VSV challenged WISH cells (Figure 4). According to the invention, when 10 pM IFN β is mixed with varying concentrations of recombinant soluble wild type IFNAR2 and mutants modified in residues H78 or N100 or in both (H78A or N100A, and IFNAR EC mutated in two amino acids H78A/N100A, H78A/N100D and H78A/N100H wherein the amino acid N100 is mutated into alanine, aspartic acid and histidine respectively) the occlusion of IFN (bound IFN at equilibrium conditions) and the residual antiviral activity obtainable with wild type IFNAR2 could be accomplished using lower concentrations of IFNAR mutants than wild type protein. The best results were obtained with mutants modified

in both residues, particularly when both amino acids were mutated to alanine, H78A/N100A IFNAR. e.g. in order to get 80% of IFN β bound (8 pM occluded and 2 pM free IFN β) about 30 fold less H78A/N100A IFNAR mutant is required over the wild type IFNAR protein. This result show that the double mutated IFNAR2 occlude more effectively IFN β and administration of considerably lower amounts will be required to fulfill its carrier activity towards IFN β .

The advantages of using the mutant EC receptor are that (I) it is possible to administrate lower quantities (thus technically feasible) of the receptor as a carrier (II) because of the stabilizing activity of the mutant it is possible to reduce the amount of IFN β administrated, and consequently to reduce some of the unwanted side effects of interferon treatment (III) the increase in the activity by the mutant is specific to IFN β , and (IV) that in some inflammatory disorders, where it may be required to lower the IFN concentrations, it is possible under certain conditions to use this mutant as an effective antagonist specifically towards IFN β , but not IFN α 2.

MIFNAR2-EC may be administered alone to stabilize and enhance the activity of endogenous IFN β , this is particularly useful for the treatment of patients having a disease or condition which naturally causes the induction of native IFN, so that the IFN will already be circulating in the body for its intended natural effect of fighting such disease or condition. This mutant will act specifically on endogenous IFN β , but less towards IFN α 2. Alternatively, MIFNAR2-EC may be co-administrated together with IFN β or administrated covalently bound to IFN β . Preferably, MIFNAR2 and IFN β used to generate the complex are recombinant molecules.

The technology required to produce the fusion protein and or covalently bound protein is similar to the wild type IFNAR/IFN complex described in detail in WO9932141, wherein the IFNAR2 mutated in H78 and N100 (MIFNAR2) is used instead of the wild type version.

The implications of using a MIFNAR2/ IFN β complex according to the invention are that it has similar potency and enhanced activity as compared to the wild type

IFNAR2/ IFN β complex, but lower concentrations of the IFNAR2 EC are required and may be used for a variety of therapeutic indications in which IFN by itself is active.

These indications include those in which free IFNs have shown some therapeutic activity, such as anti-viral, anti-cancer and immune modulatory activity. It is expected that the mutant IFNAR2/IFN complex, by virtue of its greater potency, enhanced activity and/or improved pharmacokinetics (i.e. half-life), will be more efficacious in treating viral, oncologic and immune disorders.

When administered in vivo, the interferon receptor complex enhances the bioavailability, pharmacokinetics, and/or pharmacodynamics of the IFN, thus augmenting the anti-viral, anti-cancer and immune modulating properties of the IFN.

The preferred molecules for use in the complexes of the present invention have the sequence of a native IFN and MIFNAR2. The native sequence is that of a naturally occurring human IFN or IFNAR. Such sequences are known and can be readily found in the literature. Naturally occurring allelic variations are also considered to be native sequences.

The present invention also concerns analogs of the above MIFNAR2 EC and IFN β . Such analogs may be ones in which up to about 30, preferably up to 20 and most preferably 10 amino acid residues may be deleted, added or substituted by others in the proteins. These analogs are prepared by known synthesis and/or by site-directed mutagenesis techniques or any other known technique suitable therefore.

Any such analog preferably has a sequence of amino acids sufficiently duplicative of that of the basic MIFNAR2 and IFN β such as to have substantially similar activity thereto. Thus, it can be determined whether any given analog has substantially the same activity and/or stability as the protein and complex of the invention by means of routine experimentation, comprising subjecting each such analog to binding and biological activity tests. MIFNAR2 EC analogs may bind IFN β with at least 10 folds and about 50 to 100 fold higher affinity over the wild type protein wherein the affinity towards IFN α 2 is not significantly changed. The MIFNAR2 EC analogs may exhibit a

K_d of about 30 pM and lower towards IFN β . The binding tests for MIFNAR2 and IFN interaction may involve analytical gel filtration, optical heterogeneous phase detection (such as surface plasmon resonance [SPR], or reflectometric interference spectroscopy [RifS] which resembles the widely used BIACORE technique) and fluorescent spectroscopy (Piehler and Schreiber 1999A Piehler and Schreiber 2001).

Analogues of the complex which can be used in accordance with the present invention, or nucleic acid sequence coding therefore, include a finite set of substantially corresponding sequences as substitution peptides or polynucleotides which can be routinely obtained by one of ordinary skill in the art, without undue experimentation, based on the teachings and guidance presented herein. For a detailed description of protein chemistry and structure, see Schulz et al, Principles of Protein Structure, Springer Verlag, New York (1978); and Creighton, T.E., proteins: Structure and Molecular Properties, W.H. Freeman & Co, San Francisco (1983), which are hereby incorporated by reference.

For a presentation of nucleotide sequence substitutions, such as codon preferences, see Ausubel et al (1987, 1992), A.1. I-A. 1.24, and Sambrook et al (1987, 1992), 6.3 and 6.4. at Appendices C and D.

Preferred changes for analogues in accordance with the present invention are what are known as "conservative" substitutions. Conservative amino acid substitutions of those in the sequence of the proteins in the invention may include synonymous amino acids within a group, which have sufficient similar physicochemical properties that substitution between members of the group will preserve the biological function of the molecule (Grantham, 1974). It is clear that insertions and deletions of amino acids may also be made in the above-defined sequences without altering their function, particularly if the insertions or deletions only involve a few amino acids, e.g., under thirty, and preferably under ten, and do not remove or displace amino acids which are critical to a functional conformation, e.g., cysteine residues (Anfinsen, 1973). Analogues produced by such deletions and or insertions come within the purview of the present invention. Preferably, the synonymous amino acid groups are those defined in Table I. More preferably, the synonymous amino acid groups are those defined in Table II; and

most preferably the synonymous amino acid groups are those defined 5 in Table III.

TABLE I

Preferred Groups of Synonymous Amino Acids

Amino Acid	Synonymous Group
Ser	Ser, Thr, Gly, Asn
Arg	Arg, Gln, Lys, Glu, His
Leu	Ile, Phe, Tyr, Met, Val, Leu
Pro	Gly, Ala, Thr, Pro
Thr	Pro, Ser, Ala, Gly, His, Gln, Thr
Ala	Gly, Thr, Pro, Ala
Val	Met, Tyr, Phe, Ile, Leu, Val
Gly	Ala, Thr, Pro, Ser, Gly
Ile	Met, Tyr, Phe, Val, Leu, Ile
Phe	Trp, Met, Tyr, Ile, Val, Leu, Phe
Tyr	Trp, Met, Phe, Ile, Val, Leu, Tyr
Cys	Ser, Thr, Cys
His	Glu, Lys, Gln, Thr, Arg, His
Gln	Glu, Lys, Asn, His, Thr, Arg, Gln
Asn	Gln, Asp, Ser, Asn
Lys	Glu, Gln, His, Arg, Lys
Asp	Glu, Asn, Asp
Glu	Asp, Lys, Asn, Gln, His, Arg, Glu
Met	Phe, Ile, Val, Leu, Met
Trp	Trp

TABLE 2

More Preferred Groups of Synonymous Amino Acids

Amino Acid	Synonymous Group
Ser	Ser
Arg	His, Lys, Arg
Leu	Leu, Ile, Phe, Met
Pro	Ala, Pro
Thr	Thr
Ala	Pro, Ala
Val	Val, Met, Ile
Gly	Gly
Ile	Ile, Met, Phe, Val, Leu
Phe	Met, Tyr, Ile, Leu, Phe
Tyr	Phe, Tyr
Cys	Cys, Ser
His	His, Gln, Arg
Gln	Glu, Gln, His
Asn	Asp, Asn
Lys	Lys, Arg
Asp	Asp, Asn
Glu	Glu, Gln
Met	Met, Phe, Ile, Val, Leu
Trp	Trp

TABLE 3

Most Preferred Groups of Synonymous Amino Acids

Amino Acid	Synonymous Group
Ser	Ser
Arg	Arg
Leu	Leu, Ile, Met
Pro	Pro
Thr	Thr
Ala	Ala
Val	Val
Gly	Gly
Ile	Ile, Met, Leu
Phe	Phe
Tyr	Tyr
Cys	Cys, Ser
His	His
Gln	Gln
Asn	Asn
Lys	Lys
Asp	Asp
Glu	Glu
Met	Met, Ile, Leu
Trp	Met

Examples of production of amino acid substitutions in proteins which can be used for obtaining analogs of MIFNAR2 and IFN for use in the present invention include any known method steps, such as presented in U.S. patents RE 33,653; 4,959,314;

4,588,585 and 4,737,462, to Mark et al; 5,116,943 to Koths et al; 4,965,195 to Namen et al; and 5,017,691 to Lee, et al, and lysine substituted proteins presented in US patent 4,904,584 (Shaw et al).

The term "essentially corresponding to" is intended to comprehend analogs with minor changes to the sequence of the basic MIFNAR2 EC which do not affect the basic characteristics thereof e.g. its specific enhanced binding and affinity to IFN β . The type of changes which are generally considered to fall within the "essentially corresponding to" language are those which would result from conventional mutagenesis techniques of the DNA encoding the complex of the invention, resulting in a few minor modifications, and screening for the desired activity in the manner discussed above.

Preferably, the MIFNAR2 portion of the complex will have a core sequence which is the same as that of the native sequence or biologically active fragment thereof, or a variant thereof which has an amino acid sequence having at least 70% identity to the native amino acid sequence and retains the biological activity thereof. More preferably, such a sequence has at least 85% identity, at least 90% identity, or most preferably at least 95% identity to the native sequence.

With respect to the IFN portion of the complex, the core sequence which may be used is the native sequence, or a biologically active fragment thereof, or a variant thereof which has an amino acid sequence having at least 70% identity thereto, more preferably, at least 85% or at least 90% identity, and most preferably at least 95% identity. Such analogs must retain the biological activity of the native IFN sequence or fragment thereof, or have antagonist activity as discussed herein below.

The term "sequence identity" as used herein means that the sequences are compared as follows. The sequences are aligned using Version 9 of the Genetic Computing Group's GAP (global alignment program), using the default (BLOSUM62) matrix (values -4 to +11) with a gap open penalty of -12 (for the first null of a gap) and a gap extension penalty of -4 (per each additional consecutive null in the gap). After alignment, percentage identity is calculated by expressing the number of matches as a percentage

of the number of amino acids in the claimed sequence.

Analogous in accordance with the present invention may also be determined in accordance with the following procedure. With respect to either the MIFNAR portion of the complex or the IFN portion of the complex, the DNA of the IFNAR and IFN sequence are known to the prior art and is either found in the literature cited in the background section of the present specification or can be readily located by those of ordinary skill in the art. Polypeptides encoded by any nucleic acid, such as DNA or RNA, which hybridize to the complement of the native DNA or RNA under highly stringent or moderately stringent conditions, as long as that polypeptide maintains the biological activity of the native sequence or, in the case of IFN, either maintains the biological activity of MIFNAR2 or possesses antagonistic activity, are also considered to be within the scope of the present invention.

"stringent conditions" refers to hybridization and subsequent washing conditions, which those of ordinary skill in the art conventionally refer to as "stringent". See Ausubel et al., *Current Protocols in Molecular Biology*, supra, Interscience, N.Y., §§6.3 and 6.4 (1987, 1992), and Sambrook et al. (Sambrook, J. C., Fritsch, E. F., and Maniatis, T. (1989) *Molecular Cloning: A Laboratory Manual*, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY).

Without limitation, examples of stringent conditions include washing conditions 12-20°C below the calculated T_m of the hybrid under study in, e.g., 2 x SSC and 0.5% SDS for 5 minutes, 2 x SSC and 0.1% SDS for 15 minutes; 0.1 x SSC and 0.5% SDS at 37°C for 30-60 minutes and then, a 0.1 x SSC and 0.5% SDS at 68°C for 30-60 minutes. Those of ordinary skill in this art understand that stringency conditions also depend on the length of the DNA sequences, oligonucleotide probes (such as 10-40 bases) or mixed oligonucleotide probes. If mixed probes are used, it is preferable to use tetramethyl ammonium chloride (TMAC) instead of SSC. See Ausubel, supra.

"Functional derivatives" as used herein covers derivatives which may be prepared from the functional groups which occur as side chains on the residues or the N- or C-terminal groups, by means known in the art, and are included in the invention as long as they remain pharmaceutically acceptable, i.e., they do not destroy the biological activity of the corresponding protein of the complex as described herein and do not

confer toxic properties on compositions containing it or the complex made therefore. Derivatives may have chemical moieties, such as carbohydrate or phosphate residues, provided such a fraction has the same biological activity and remains pharmaceutically acceptable.

For example, derivatives may include aliphatic esters of the carboxyl of the carboxyl groups, amides of the carboxyl groups by reaction with ammonia or with primary or secondary amines, N-acyl derivatives or free amino groups of the amino acid residues formed with acyl moieties (e.g., alkanoyl or carbocyclic aroyl groups) or O-acyl derivatives of free hydroxyl group (e.g., that of seryl or threonyl residues) formed with acyl moieties. Such derivatives may also include for example, polyethylene glycol side-chains, which may mask antigenic sites and extend the residence of the complex or the portions thereof in body fluids.

The term "derivatives" is intended to include only those derivatives that do not change one amino acid to another of the twenty commonly occurring natural amino acids.

The term "salts" herein refers to both salts of carboxyl groups and to acid addition salts of amino groups of the complex of the invention or analogs thereof. Salts of a carboxyl group may be formed by means known in the art and include inorganic salts, for example, sodium, calcium, ammonium, ferric or zinc salts, and the like, and salts with organic bases as those formed, for example, with amines, such as triethanolamine, arginine or lysine, piperidine, procaine and the like. Acid addition salts include, for example, salts with mineral acids, such as, for example, hydrochloric acid or sulfuric acid, and salts with organic acids, such as, for example, acetic acid or oxalic acid. Of course, any such salts must have substantially similar biological activity to the complex of the invention or its analogs.

The term "biological activity" as used herein is interpreted as follows. Insofar as the MIFNAR2 portion of the complex is concerned, the important biological activity is its ability to bind to IFN β with increased affinity. Thus, analogs or variants, salts and functional derivatives must be those chosen so as to maintain this interferon-binding ability.

This can be tested by routine binding assay experiments. In addition, fragments of the MIFNAR2, or analogs thereof, can also be used as long as they retain their interferon-enhanced binding activity. Fragments may readily be prepared by removing amino acids from either end of the interferon-binding polypeptide and testing the resultant for interferon-binding properties.

Proteases for removing one amino acid at a time from either the N-terminal or the C-terminal of a polypeptide are known, and so determining fragments, which retain interferon-binding ability, involves only routine experimentation.

Additionally, the polypeptide which has such interferon-binding activity, be it MIFNAR2, sMIFNAR2, an analog or variant, salt, functional derivative or fragment thereof, can also contain additional amino acid residues flanking the interferon-binding polypeptide. As long as the resultant molecule retains the increased interferon-binding ability of the core polypeptide, one can determine whether any such flanking residues affect the basic and novel characteristics of the core peptide, i.e., its interferon-binding characteristics, by routine experimentation. The term "consisting essentially of", when referring to a specified sequence, means that additional flanking residues can be present which do not affect the basic and novel characteristic of the specified sequence. This term does not comprehend substitutions, deletions or additions within the specified sequence.

While MIFNAR2 or sMIFNAR2 have been used throughout this description and in the examples, it should be understood that this is merely the preferred example and that the IFNAR1 subunit, and particularly its extracellular domain, may be used together with MIFNAR2.

It should be noted that the expressions used: MIFNAR2, sMIFNAR2 and MIFNAR2 EC are interchangeable.

With respect to the interferon part of the complex of the present invention, the biological activity which must be maintained in any analog or variant, salt, functional derivative or fragment is the activity of the interferon relied upon for the intended utility. In most instances, this will be the ability to bind to a native cell surface receptor

and thereby mediate signal production by the receptor. Thus, any such analog, derivative or fragment should maintain such receptor agonist activity to be useful in the present invention for such a utility. On the other hand, it is sometimes useful to have a molecule with antagonist activity on the receptor so as to prevent the biological activity of native interferon. Such an antagonist can also be used for prolonged beneficial effect by means of the complex of the present invention. For such utilities in which it is desired to eliminate an undesired effect of interferon, analogs which are still bound by the receptor and by the IFNAR portion of the complex but which do not mediate a signal and block signal generation by the native interferon on that receptor, may also be considered to be biologically active for the purpose of this invention and to be encompassed by the term interferon when used with respect to the complexes of the present invention. Straightforward assays can determine whether any such analog maintains such receptor agonist activity or has receptor antagonist activity and would, thus, be useful for one of the utilities of the present invention.

The present invention also concerns DNA sequences encoding the above complex of the invention and its analogs, as well as DNA vectors carrying such DNA sequences for expression in suitable prokaryotic or eukaryotic host cells.

The ability to generate large quantities of heterologous proteins using a recombinant protein expression system has led to the development of various therapeutic agents, e.g., t-PA and EPO (Edington, 1995). The various expression hosts from which recombinant proteins can be generated range from prokaryotic in origin (e.g., bacteria) (Olins, 1993), through lower eukaryotes (e.g., yeast) (Ratner, 1989) to higher eukaryotic species (e.g., insect and mammalian cells (Reuveny, 1993; Reff, 1993). All of these systems rely upon the same principle - introducing the DNA sequence of the protein of interest into the chosen cell type (in a transient or stable fashion, as an integrated or episomal element) and using the host transcription, translation and transportation machinery to over-express the introduced DNA sequence as a heterologous protein (Keown, 1990).

In addition to the expression of native gene sequences, the ability to manipulate DNA at the nucleotide level has expedited the development of novel engineered sequences which, although based on natural proteins, possess novel activities as a result of the

alteration in primary protein structure (Grazia, 1997).

Moreover, chosen sequences of DNA can be physically linked to generate transcripts which develop into novel fusion proteins where once independent proteins are now expressed as one polypeptide unit (Ibanez, 1991). The activity of such fusion proteins can be different, e.g., more potent, than either of the individual proteins (Curtis, 1991).

Human IFN β may be derived from a production process, which uses the mammalian Chinese hamster ovary cell (CHO) as disclosed in EP220574. Type 1 interferons can be expressed in a variety of host cells including bacteria (Utsumi, 1987), insect (Smith, 1983) and human (Christofinis, 1981). Human MIFNAR2 may be expressed using the CHO host cell. Alternatively, soluble receptors, such as sMIFNAR2, may be expressed successfully in bacterial expression systems (Terlizzese, 1996).

The invention also concerns a pharmaceutical composition comprising as active ingredient an, MIFNAR2, MIFNAR2 EC, MIFNAR2 EC/IFN complex or analogs thereof or mixtures thereof or salts thereof and a pharmaceutical acceptable carrier, diluent or excipient. An embodiment of the pharmaceutical composition of the invention includes a pharmaceutical composition for enhanced IFN type action, in the treatment of viral diseases, in anti-cancer therapy, in immune modulation therapy and other applications of interferons and cytokines related thereto.

The pharmaceutical compositions of the invention are prepared for administration by mixing the complex or its analogs with physiologically acceptable carriers and/or stabilizers and/or excipients, and prepared in dosage form, e.g., by lyophilization in dosage vials. The method of administration can be via any of the accepted modes of administration for similar agents and will depend on the condition to be treated, e.g., intravenously, intramuscularly, and subcutaneously, by local injection or topical application, or continuously by infusion, etc. The amount of active compound to be administered will depend on the route of administration, the disease to be treated and the condition of the patient.

Local injection, for instance, will require a lower amount of the protein on a body

weight basis than will intravenous infusion.

Free IFN β has a tendency to oligomerize. To suppress this tendency, present day formulations of IFN β have an acidic pH, which may cause some localized irritation when administered. As MIFNAR2 can serve as a superior stabilizing over the wild type version factor for IFN β and thereby prevent oligomerization, its use in IFN β formulations can serve to stabilize the IFN β and thereby obviate the necessity of acidic formulations. Accordingly, a non-acidic pharmaceutical composition containing IFN β and MIFNAR2, along with other conventional pharmaceutically acceptable excipients, is also a part of the present invention.

The present invention also concerns uses of the mutant interferon receptor and - mutant interferon receptor and interferon complexes or its analogs or mixtures thereof for anti-viral, anti-cancer and immune modulation therapy. Specifically, the mutant interferon receptor and - mutant interferon receptor and interferon complexes of this invention are useful for anti-viral therapy in such therapeutic indications as chronic granulomatous disease, condyloma acuminatum, juvenile laryngeal papillomatosis, hepatitis A and chronic infection with hepatitis B and C viruses.

In particular, the mutant interferon receptor and - mutant interferon receptor and interferon complexes of this invention are useful for anti-cancer therapy in such therapeutic indications as hairy cell leukemia, Kaposi's sarcoma, multiple myeloma, chronic myelogenous leukemia, non-Hodgkins's lymphoma and melanoma.

The mutant interferon receptor and - mutant interferon receptor and interferon complexes of this invention are also useful for immune modulation therapy, such as multiple sclerosis, rheumatoid arthritis, myasthenia gravis, diabetes, AIDS, lupus, etc..

The mutant interferon receptor and - mutant interferon receptor and interferon complexes are also useful for treating neurodegenerative diseases, preferably multiple sclerosis.

Likewise, the present invention also concerns the complex or analogs thereof or mixtures thereof for use in the preparation of medicaments for treating the above-mentioned ailments or for use in the above noted indications.

EXAMPLES

Example 1: Protein expression and purification.

IFNAR2-EC (extracellular domain) and IFN α was expressed in *E. coli* purified by ion exchange and size-exclusion chromatography as described (Piehler & Schreiber, 1999A). The levels of expression of IFNAR2-EC mutants were as high as the wild type. Wild type, glycosylated IFN β produced in CHO (disclosed in EP220574). Protein concentrations were determined from absorbance at 280 nm (Piehler & Schreiber, 1999A) with 1:280 = 18,070 M⁻¹ for IFN α 2, 1:280 = 30,050 M⁻¹ for IFN β and 1:280 = 26,500 M⁻¹ for IFNAR2-EC (corrected to 1:280 = 21,100 M⁻¹ for the tryptophan mutants of IFNAR2- EC W102A and W74F). Protein purity was analyzed by SD5-PAGE under non-reducing conditions.

Example 2: Generation of IFNAR EC mutants.

Site-directed mutagenesis was carried out by PCR with the template pT72CR2 (Piehler and Schreiber 1999) and with 18-21 nucleotide primers containing the mutated codon using high fidelity polymerases *pwo* (Boehringer Mannheim) and *Pfu* (Stratagene) as described in detail (Albeck & Schreiber, 1999). After phosphorylation and ligation, the mutated plasmids were used to transform *E. coli* TG1 cells. The sequence of the whole expressed gene containing the mutation was verified by DNA sequencing (Ausubel *et al.*, Current Protocols in Molecular Biology, Greene Publications and Wiley Interscience, New York, NY, 1987-1995; Sambrook *et al.*, Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, Cold Spring Harbor, NY, 1989).

Mutants were generated in which two amino acid residues, histidine 78 (H78) and Asparagine 100 (N100), were mutated: A- both to alanine residue (H78A/N100A mutant). B- to alanine and aspartic acid respectively (H78A/N100D) and C- to alanine and histidine respectively (H78A/N100H).

Example 3: Thermodynamic and kinetic analysis.

All thermodynamic and kinetic data were obtained from label-free heterogeneous phase detection. The interaction between IFN β 2 and IFNAR2-EC was monitored by reflectometric interference spectroscopy (RIfS) under flow-through conditions as described (Piehler & Schreiber, 1999A). This technique is similar to Biacore and is used to accurately measure affinity of binding between two proteins. IFNAR2-EC (wild-type or mutant) was immobilized through immobilized specific antibodies (as described by Piehler and Schreiber 2001). All measurements with IFN β , IFN α 2 and IFNAR2-EC were carried out in 50 mM Hepes with 500 mM NaCl and 0.01 % Triton X100 at pH 7.4. The interaction was measured at 500 mM NaCl in order to eliminate non-specific interactions with the surface, which was observed with IFN β at 150 mM NaCl.

Association and dissociation kinetics were measured by standard injection protocols and corrected by blank runs. Dissociation rate constants were measured at IFN concentration in the range of 1-1000 nM in order to saturate the surface. The total range of dissociation was used for fitting a 1:1 kinetic model (Piehler & Schreiber, 2001).

Example 4: Anti viral activity assay.

Anti-viral activity of IFN β was assayed as the inhibition of the cytopathic effect of vesicular stomatitis virus (VSV) on human WISH cells (Rubinstein *et al.*, 1981).

Example 5: Measurement of IFN binding to mutant IFNAR2.

Binding of the IFN β and IFN α 2 to the H78A/N100A mutant (example 2) was measured and compared to the wild type EC receptor by RifS (example 3). While the association rate of IFN β to the H78A/N100A mutant was found to be similar to that of the wild type (Figure 3) the disassociation rate was found to be significantly lower. The calculated affinity of IFN β to H78A/N100A mutant is about 30 pM versus the affinity to the WT protein of about 3 nM. In contrast to IFN β , both the association and disassociation rate of IFN α 2 to the H78A/N100A mutant, were found to be similar to the rates obtained with the wild type protein (Figure 3). These results show that the affinity of the mutant mutant was found to be approximately 100 times higher than the wild type towards IFN β and unchanged towards IFN α 2.

Example 6: Relative affinities of interferon towards the mutant IFNAR2.

The binding and affinities of IFNAR EC receptor and receptor mutants (example 2) to IFN β and IFN α 2 were measured using RifS, with IFNAR2 immobilized to the surface trough specific antibodies (example 3). After measuring the affinities, the relative affinities were obtained by comparing the K_d of the mutant receptor over the K_d of the wild type receptor (Table 1).

Table 1

ifnar2	IFN α 2	IFN β
wt	1.0	1.0
H78A	0.4	4.6
N100A	2.0	7.3
H78A/N100A	0.7	>50
H78A/N100D	1.0	40.0
H78A/N100H	0.9	26.0

The K_d of binding of interferon to IFNAR2 extracellular domain (EC) was measured by RfS and was found to be about 3nM (example 5). The K_d of IFN β binding to H78A/N100A (EC) mutant was about 30 pM. The exact measurement of K_d for this mutant was not possible, because binding was too tight to get good data from RfS. The K_d of IFN α 2 to the H78A/N100A EC mutant was found to be similar to the wild type receptor. The results in Table 1 show the relative affinities of the IFNAR EC mutants compared to the wild type IFNAR2 receptor. The mutants were the following: mutated in one amino acid residue, H78A or N100A, and mutated in two amino acids H78A/N100A, H78A/N100D and H78A/N100H wherein the amino acid N100 is mutated into alanine, aspartic acid and histidine respectively (example 2). The results demonstrate that the single mutations in IFNAR2 increase the affinity of the complex from 4.6 up to 7.3 fold, while the double mutation causes a synergistic effect, increasing the affinity of the complex by 26 and to above 50-fold. The best mutant in terms of affinity was found to be the double mutant with the N100 modified to alanine, exhibiting over 50 fold increased affinity versus the wild type version.

Example 7: Occlusion of interferon beta by the IFNAR2 mutant.

The capability of IFNAR2 wild type and mutants to serve as carriers of IFN β was compared. For that purpose antiviral activity of IFN β left (free) in samples comprising a constant concentration of IFN β (10 pM) mixed with varying concentrations of recombinant soluble IFNAR2 or IFNAR2 mutants (example 6) was monitored. In the antiviral assay, the mixture (IFNAR2/IFN complex) was added to WISH cells (human amniotic cells). These WISH cells were then challenged with vesicular stomatitis virus (VSV), and the residual (free) anti-viral activity of IFN β was monitored as the degree of cell survival following 24-hour incubation (example 4). The free IFN β present in samples having different WT and mutant IFNAR2 (R2) concentration was determined from a survival dose curve of antiviral activity as a function of IFN β concentration carried out in the absence of IFNAR2 (Figure 2 upper plot).

The mutants tested were the following: IFNAR EC mutated in one amino acid residue. H78A or N100A, and mutated in two amino acids H78A/N100A, H78A/N100D and H78A/N100H wherein the amino acid N100 is mutated into alanine, aspartic acid and histidine respectively example 2). The double mutant of IFNAR2 H78A/N100A (example 2) has the highest affinity of all the generated mutants (K_d of about 30 pM and lower see examples 5 and 6).

Figure 4 shows that in the presence of 2.5 nM of wild type IFNAR2 about 20% IFN β is bound to the soluble receptor (occluded), while in the presence of only 0.2 nM of the double mutant H78A/N100A 50 % of IFN β is bound and using only 0.4nM of H78A/N100A mutant 80 % of the IFN β is bound. The biological assay demonstrated also, that the same extent of occluded IFN β (bound of IFN β under equilibrium conditions) and the residual antiviral activity (free IFN β) obtainable with wild type IFNAR2 could be accomplished using about 30 fold lower concentration of the H78A/N100A IFNAR2 mutant. The results show also that the double modified mutant gave the best results, particularly the one in which both amino acids were mutated to alanine, H78A/N100A IFNAR2.

This result shows that the double mutated IFNAR2 occlude more effectively IFN β and therefore administration of considerably lower amounts will be required to accomplish its carrier activity.

REFERENCES

- Alam et al. Pharmaceutical Research 14:546-549 (1997).
- Anfinsen. " Science 181:223-230 (1973).
- Ausubel et al. Current Protocols in Molecular Biology, Greene Publications and Wiley Interscience (New York, 1987-1992).
- Baron et al. Antiviral Res. 24:97-110 (1994).
- Baron. et al. J. Am. Med. Assoc. 266:1375-1383 (1991)
- Christofinis, G.J Journal of General Virology 52:169-171 (1981)
- Colamonici et al, J. Immunol. 148:2126- 2132 (1992).
- Colamonici et al, J. Biol. Chem. 268:10895-10899 (1993).
- Curtis, B.M., Proc. Natl. Acad. Sci. 88:5809-5813 (1991).
- Domanski et al, The Journal of BioloGical Chemistry 270:6 (1995).
- Duncan et al. J. Exp. Med. 184:2043-2048 (1996).
- Dron et al. "Interferon α/β gene structure and regulation" in Interferon: principles and Medical Applications, Baron et al, Editors, (University of Texas Medical Branch: Galveston, TX, 1992) pp. 33-45
- Edington, S.M., "Biotech Products as Drug Leads" BioTechnology 13:649 (1995)
- Fierlbeck et al, Journal of Interferon and Cytokine Research 16:777 (1996).
- Grantham. Science 185:X62-X64 (1974).
- Grazia Cusi, Mo, Immunotechnology 3:61-69 (1997).
- Ibanez, C.F., EMBO Journal 10:2105-2110 (1991).
- Jacobs L. et al. Arch Neurol 1987 Jun;44(6):589-95.
- Keown, W.A., Methods in Enzymology 185:527-537 (1990).
- Lengyl, P. Ann. Rev. Biochem. 51:251-282 (1982).
- Lutfalla et al. EMBO Journal 14:5100-5108 (1995).
- Novick et al, FEBS Lett. 314:445-448 (1992).
- Novick et al, Cell 77:391-400 (1994).
- Novick et al. J. Leuk. Bio. 57:712-718 (1995).
- Piebler and Schreiber J. ol. Biol. 1999A 289, 57-67.
- Piebler and Schreiber J. ol. Biol. 1999B 294, 223-237.
- Piebler and Schreiber Analytical Biochemistry 289, 173-186.
- Platanias et al, 1993 J. Immunology 150 : 3382-3388.
- Platanias et al, 1996 J.Biol. Chem. 271 : 23630-3.
- Salmon et al, 1996 Journal of Interferon and Cytokine Research 16 : 759.
- Sharf et al, 1995 J. Biol. Chem. 270 : 13063-9.
- Tan et al, 1973. J. Exp. Med. 137: 317-330.

Uze et al, 1990 Cell 60 : 225-34.

Yang et al, 1996 J. Biol. Chem. 271 : 8057-61.

Yan et al. , 1996 Mol. Cell Bio. 16 : 2074-82.

527.ST25
SEQUENCE LISTING

<110> YEDA RESEARCH AND DEVELOPMENT CO. Ltd.

<120> IFNAR2 MUTANTS, THEIR PRODUCTION AND USE

<130> 527

<160> 1

<170> PatentIn version 3.1

<210> 1

<211> 215

<212> PRT

<213> Homo sapiens

<400> 1

Met Ala Ser Tyr Asp Ser Pro Asp Tyr Thr Asp Glu Ser Cys Thr Phe
1 5 10 15

Lys Ile Ser Leu Arg Asn Phe Arg Ser Ile Leu Ser Trp Glu Leu Lys
20 25 30

Asn His Ser Ile Val Pro Thr His Tyr Thr Leu Leu Tyr Thr Ile Met
35 40 45

Ser Lys Pro Glu Asp Leu Lys Val Val Lys Asn Cys Ala Asn Thr Thr
50 55 60

Arg Ser Phe Cys Asp Leu Thr Asp Glu Trp Arg Ser Thr His Glu Ala
65 70 75 80

Tyr Val Thr Val Leu Glu Gly Phe Ser Gly Asn Thr Thr Leu Phe Ser
85 90 95

Cys Ser His Asn Phe Trp Leu Ala Ile Asp Met Ser Phe Glu Pro Pro
100 105 110

Glu Phe Glu Ile Val Gly Phe Thr Asn His Ile Asn Val Met Val Lys
115 120 125

527.ST25

Phe Pro Ser Ile Val Glu Glu Glu Leu Gln Phe Asp Leu Ser Leu Val
 130 135 140

Ile Glu Glu Gln Ser Glu Gly Ile Val Lys Lys His Lys Pro Glu Ile
 145 150 155 160

Lys Gly Asn Met Ser Gly Asn Phe Thr Tyr Ile Ile Asp Lys Leu Ile
 165 170 175

Pro Asn Thr Asn Tyr Cys Val Ser Val Tyr Leu Glu His Ser Asp Glu
 180 185 190

Gln Ala Val Ile Lys Ser Pro Leu Lys Cys Thr Leu Leu Pro Pro Gly
 195 200 205

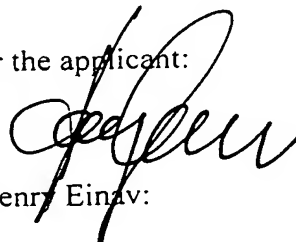
Gln Glu Ser Glu Phe Ser Glx
 210 215

CLAIMS:

1. An IFNAR2 mutant mutated at amino acid residue histidine 78 and asparagine 100, an analogue, derivative or fragment thereof.
2. An IFNAR2 mutant according to claim 1, wherein the mutations are substitutions.
3. An IFNAR2 mutant according to claim 2, wherein the substitutions are non-conservative.
4. An IFNAR2 mutant according to anyone of claims 1, 2 or 3, wherein residue 100 is substituted by alanine, aspartic acid and histidine.
5. An IFNAR2 mutant according to anyone of claims 1 to 4, wherein residue 78 is substituted by alanine.
6. An IFNAR2 mutant according to claims 4 and 5, wherein both residues 78 and 100 are substituted by alanine.
7. An IFNAR2 mutant according to claim 1, having higher affinity to IFN β than the wild type IFNAR2.
8. An IFNAR2 mutant according to claim 7, wherein its affinity to IFN β is about 30 pM.
9. An IFNAR2 mutant according to claim 7, wherein its affinity to IFN β is about 25, preferably 50 and more preferably 100-fold higher than the affinity of the wild type IFNAR2.
10. An IFNAR mutant according to anyone of claims 1 to 9, wherein the fragment comprises the extracellular domain.
11. The use of an IFNAR2 mutant according to anyone of claims 1 to 10 for the manufacture of a medicament for modulating the in vivo effect of IFN.

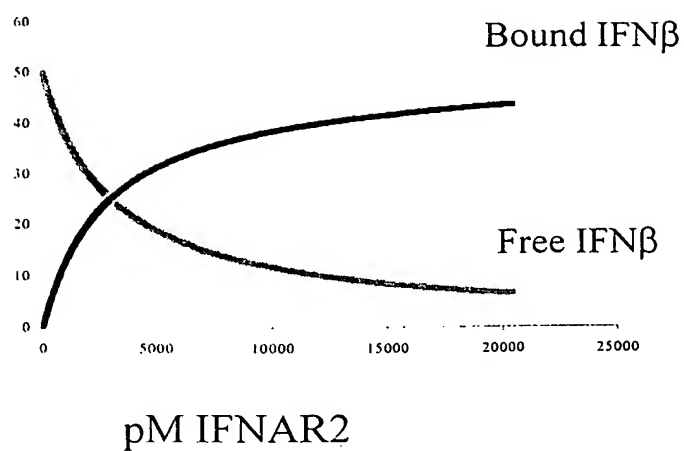
12. The use according to claim 11, for improving the activity of IFN in vivo.
13. The use according to claim 11, for inhibiting the activity of IFN in vivo.
14. The use according to claims 11, 12 and 13, wherein the IFN is IFN β .
15. A pharmaceutical composition comprising a therapeutically effective amount of an IFNAR2 mutant according to anyone of claims 1 to 10.
16. A pharmaceutical composition according to claim 15, for co-administrating with IFN.
17. A pharmaceutical composition according to claim 16, wherein the IFN is IFN β .
18. A pharmaceutical composition according to claim 17, wherein the IFNAR2 and IFN β are covalently bound.
19. A pharmaceutical composition according to claims 17 and 18, wherein the IFNAR2 mutant comprises the extracellular domain.
20. A pharmaceutical composition according to anyone of claims 15 to 19, for augmenting the anti-viral, anti-cancer and immune modulating properties of IFN.
21. A pharmaceutical composition according to anyone of claims 15 to 19, for the inhibition of immune modulating properties of IFN.
22. A pharmaceutical composition according to anyone of claims 15 to 19, for the treatment of neurodegenerative diseases.
23. A pharmaceutical composition according to claim 22, wherein the neurodegenerative disease is multiple sclerosis.
24. A pharmaceutical composition according to anyone of claims claims 20 to 23 wherein the IFN is IFN β .

For the applicant:



Henry Einav:

3 mM affinity, 50 pM interferon



50 pM affinity, 50 pM interferon

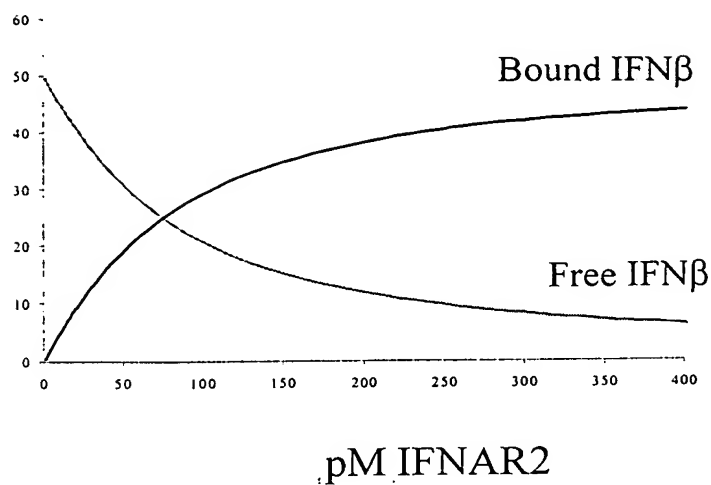


Figure 1

MASYDSPDYTDESCTFKISLRNFRSILSWELKNHSIVPTHYTLTYTIMSK	50
PEDLKVVKNCANTTRSFCDLTDEWRSTHEAYVTVLEGFSGNTTLFSCSHN	100
FWLAIDMSFEPPEFEIVGFTNHINVMVKFPSIVEEELQFDLSLVIEEQSE	150
GIVKKHKPEIKGNMSGNFTYIIDKLIPNTNYCVSVYLEHSDEQAVIKSPL	200
KCTLLPPGQSEFSZ	

Figure 2

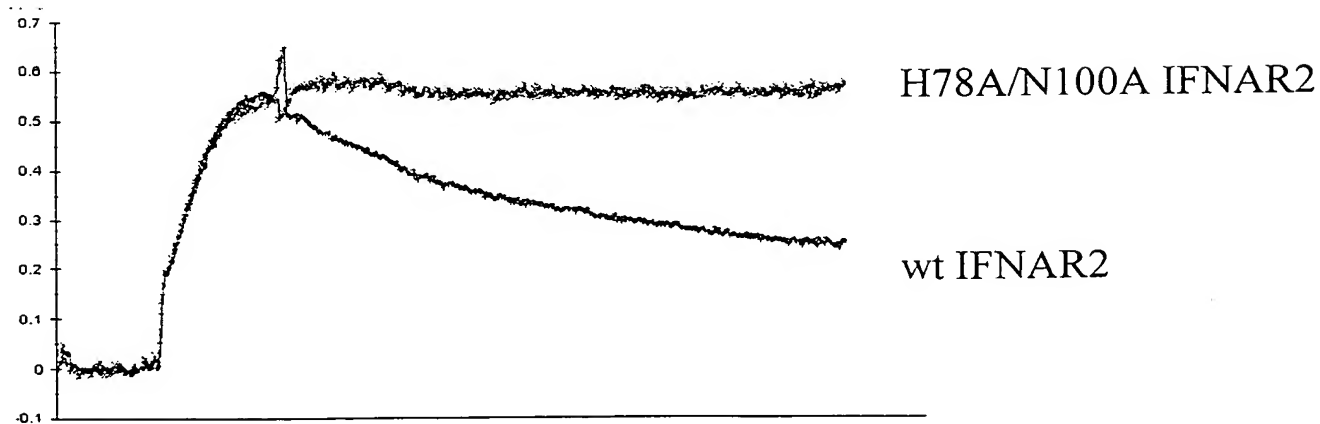
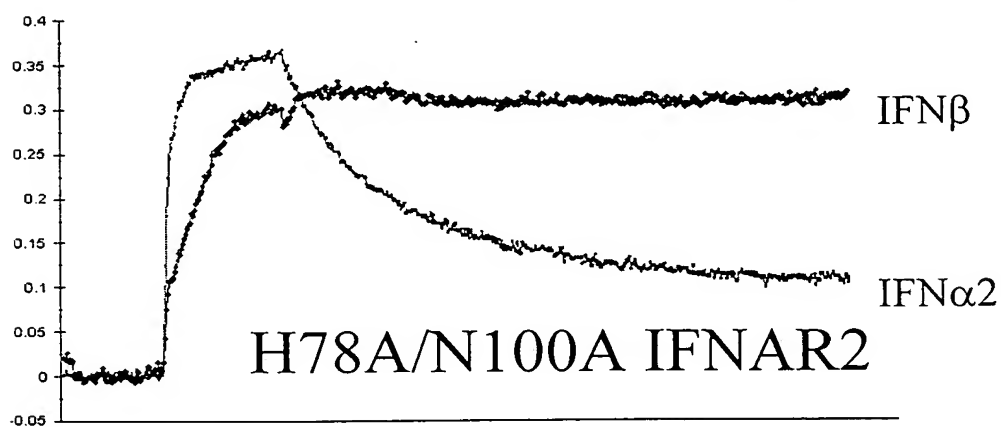
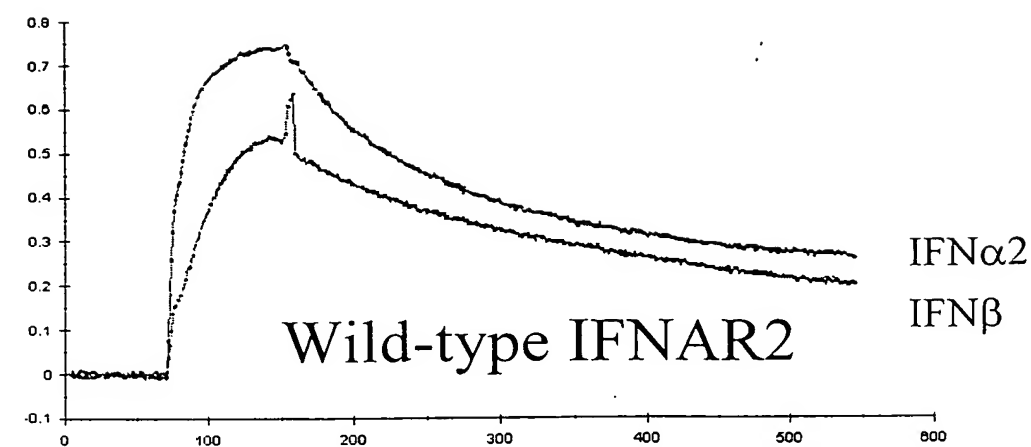


Figure 3

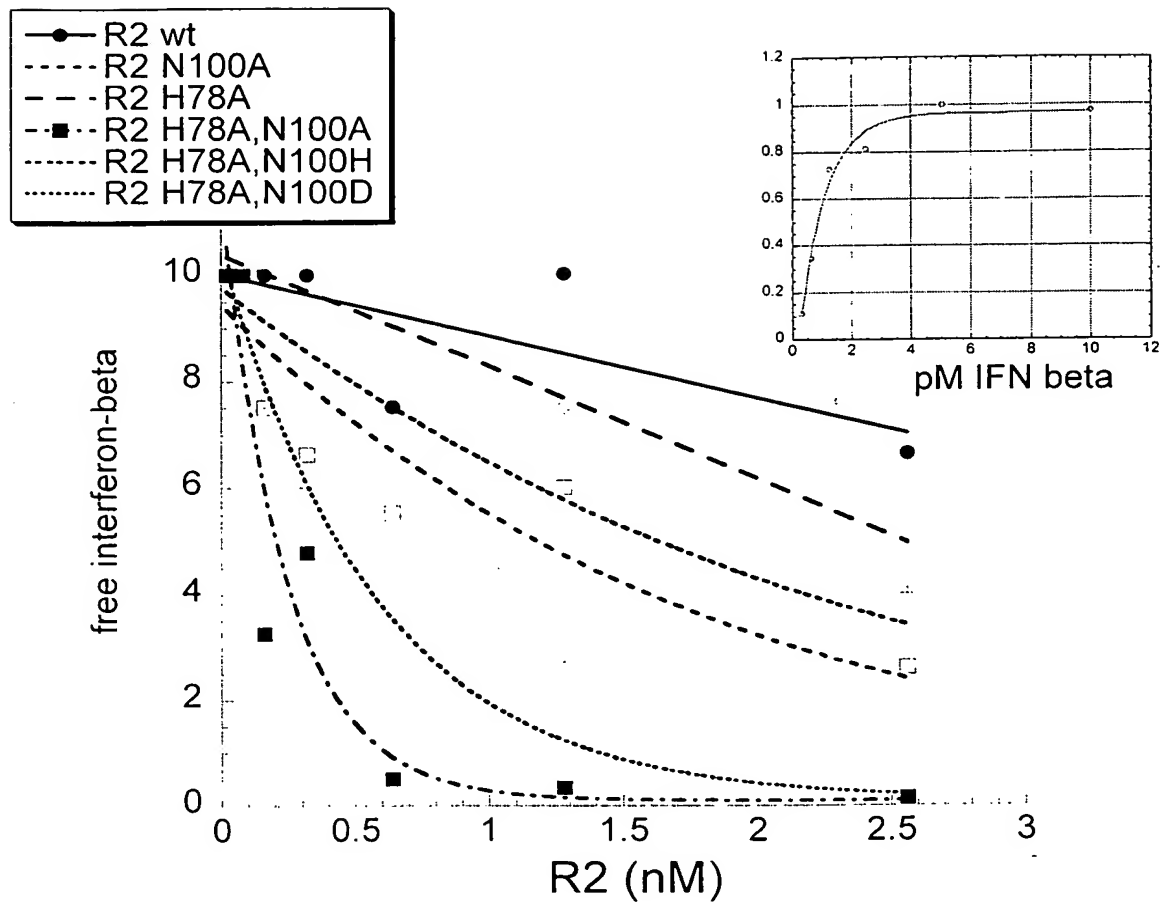


Figure 4